CHAPTER 4
DISPOSAL ALTERNATIVES

4-1. Introduction.

a. While selection of proper dredging equipment and techniques is essential for economic dredging, the selection of a disposal alternative is of equal or greater importance in determining viability of the project, especially from the environmental standpoint. There are three major disposal alternatives available:

(1) Open-water disposal.

(2) Confined disposal.

(3) Habitat development.

Each of the major disposal alternatives involves its own set of unique considerations, and selection of a disposal alternative should be made based on both economic and environmental considerations.

b. This chapter describes considerations in evaluation of disposal alternatives , primarily from an environmental standpoint. Sections on evaluation of pollution potential and sediment resuspension due to dredging apply to all disposal alternatives, while separate sections describe considerations of each of the three major disposal alternatives.

Section I. Evaluation of Dredged Material Pollution Potential

4-2. Influence of Disposal Conditions on Environmental Impact.

a. As discussed in WES TR DS-78-6, the properties of a dredged sediment affect the fate of contaminants, and the short- and long-term physical and chemical environment of the dredged material at the disposal site influences the environmental consequences of contaminants. These factors should be considered in evaluating the environmental risk of a proposed disposal method for contaminated sediment. The processes involved with release or immobilization of most sediment-associated contaminants are regulated to a large extent by the physical-chemical environment and the related bacteriological activity associated with the dredged material at the disposal site. Important physical-chemical parameters include pH, oxidation-reduction conditions, and salinity. Where the physical-chemical environment of a contaminated sediment is altered by disposal, chemical and biological processes important in determining environmental consequences of potentially toxic materials may be affected.

b. The major sediment properties that will influence the reaction of dredged material with contaminants are the amount and type of clay; organic matter content; amount and type of cations and anions associated with the sediment; the amount of potentially reactive iron and manganese; and the oxidation-reduction, pH, and salinity conditions of the sediment. Although each of these sediment properties is important, much concerning the release of contaminants from sediments can be inferred from the clay and organic matter content, initial and final pH, and oxidation-reduction conditions. Much of the dredged material removed during harbor and channel maintenance dredging is high in organic matter and clay and is both biologically and chemically active. It is usually devoid of oxygen and may contain appreciable sulfide. These sediment conditions favor effective retention of many contaminants, provided the dredged materials are not subject to mixing, resuspension, and transport. Sandy sediments low in organic matter content are much less effective in retaining metal and organic contaminants. These materials tend not to accumulate contaminants unless a contamination source is nearby. Should contamination of these sediments occur, potentially toxic substances may be readily released upon mixing in a water column, or by leaching and possibly plant uptake under intertidal or upland disposal conditions.

c. Many contaminated sediments are reducing and near neutral in pH, initially. Disposal into quiescent waters will generally maintain these conditions and favor contaminant retention. Certain sediments (noncalcareous and containing appreciable reactive iron and particularly reduced sulfur compounds) may become moderately to strongly acid upon gradual drainage and subsequent oxidation as may occur under upland disposal conditions. This altered disposal environment greatly increases the potential for releasing potentially toxic metals. In addition to the effects of pH changes, the release of most potentially toxic metals is influenced to some extent by oxidation-reduction conditions, and certain of the metals can be strongly affected by oxidation-reduction conditions. Thus, contaminated sandy, low organic-matter-content sediments pose the greatest potential for release of contaminants under all conditions of disposal. Sediments which tend to become strongly acid upon drainage and long-term oxidation also pose a high environmental risk under some disposal conditions. The implications of the influence of disposal conditions on contaminant mobility are discussed below.

4-3. Methods of Characterizing Pollution Potential.

a. Bioassay. Bioassay tests are used to determine the effects of a contaminant(s) on biological organisms of concern. They involve exposure of the test organisms to dredged material (or some fraction such as the elutriate) for a specified period of time, followed by determination of the response of the organisms. The most common response of interest is death. Often the tissues of organisms exposed to dredged material are analyzed chemically to determine whether they have incorporated, or bioaccumulated, any contaminants from the dredged material. Bioassays provide a direct indication of the overall biological effects of dredged material. They reflect the cumulative influence of all contaminants present, including any possible interactions of contaminants. Thus, they provide an integrated measurement of potential biological effects of a dredged material discharge. For precisely these reasons, however, a bioassay cannot be used to identify the causative agent(s) of impact in a dredged material. This is of interest, but is seldom of importance, since usually the dredged material cannot be treated to remove the adverse components even if they could be identified. Dredged material bioassay techniques for aquatic animals have been implemented in the ocean-dumping regulatory program for several years (item 1) and are easily adapted for use in fresh water. Dredged material bioassays for wetland and terrestrial plants have also been developed (item 2) and are coming into ever-wider use.

b. Water Column Chemistry. Chemical constituents contained in or associated with sediments are unequally distributed among different chemical forms depending on the physical-chemical conditions in the sediments and the overlying water. When contaminants introduced into the water column become fixed into the underlying sediments, they rarely if ever become part of the geological mineral structure of the sediment. Instead, these contaminants remain dissolved in the sediment interstitial water, or pore water, become absorbed or adsorbed to the sediment ion exchange portion as ionized constituents, form organic complexes, and/or become involved in complex sediment oxidation-reduction reactions and precipitations. The fraction of a chemical constituent that is potentially available for release to the water column when sediments are disturbed is approximated by the interstitial water concentrations and the loosely bound (easily exchangeable) fraction in the sediment. The elutriate test is a simplified simulation of the dredging and disposal process wherein predetermined amounts of dredging site water and sediment are mixed together to approximate a dredged material slurry. The elutriate is analyzed for major dissolved chemical constituents deemed critical for the proposed dredging and disposal site after taking into account known sources of discharges in the area and known characteristics of the dredging and disposal site. Results of the analysis of the elutriate approximate the dissolved constituent concentration for a proposed dredged material disposal operation at the moment of discharge. These concentrations can be compared to water quality standards and mixing zone considerations to evaluate the potential environmental impact of the proposed discharge activity in the discharge area.

c. Total or Bulk Sediment Chemistry. The results of these analyses provide some indication of the general chemical similarity between the sediments to be dredged and the sediments at the proposed disposal site. The total composition of sediments, when compared with natural background levels at the site, will also, to some extent, reflect the inputs to the waterway from which they were taken and may sometimes be used to identify and locate point source discharges. Since chemical constituents are partitioned among various sediment fractions, each with its own mobility and biological availability, a total sediment analysis is not a useful index of the degree to which dredged material disposal will affect water quality or aquatic organisms. Total sediment analysis results are further limited because they cannot be compared to any established water quality criteria in order to assess the potential environmental impact of discharge operations. This is because the water quality criteria are based on water-soluble chemical species, while chemical constituents associated with dredged material suspensions are generally in particulate/solid-phase forms or mineralogical forms that have markedly lower toxicities, mobilities, and chemical reactivities than the solution-phase constituents. Consequently, little information about the biological effects of solid-phase and mineral constituents that make up the largest fraction of dredged material can be gained from total or bulk sediment analysis.

Section II. Sediment Resuspension Due to Dredging

4-4. Factors Influencing Dredging Turbidity.

a. Occurrence and Extent. The nature, degree, and extent of sediment suspension around a dredging or disposal operation are controlled by many factors, as discussed in WES TR DS-78-13. Chief among these are: the particle size distribution, solids concentration, and composition of the dredged material; the dredge type and size, discharge/cutter configuration, discharge rate, and solids concentration of the slurry; operational procedures used; and finally the characteristics of the hydraulic regime in the vicinity of the operation, including water composition, temperature and hydrodynamic forces (i.e., waves, currents, etc.) causing vertical and horizontal mixing. The relative importance of the different factors may vary significantly from site to site.

b. Hopper Dredge. Resuspension of fine-grained maintenance dredged material during hopper dredging operations is caused by the dragheads as they are pulled through the sediment, turbulence generated by the vessel and its prop wash, and overflow of turbid water during hopper filling operations. During the filling operation, dredged material slurry is often pumped into the hoppers after they have been filled with slurry in order to maximize the amount of solid material in the hopper. The lower density, turbid water at the surface of the filled hoppers overflows and is usually discharged through ports located near the waterline of the dredge. In the vicinity of hopper dredges during maintenance operations, a near-bottom turbidity plume of resuspended bottom material may extend 2300 to 2400 ft downcurrent from the dredge. In the immediate vicinity of the dredge, a well-defined, upper plume is generated by the overflow process. Approximately 1000 ft behind the dredge the two plumes merge into a single plume (fig. 4-1). Suspended solid concentrations above ambient may be as high as

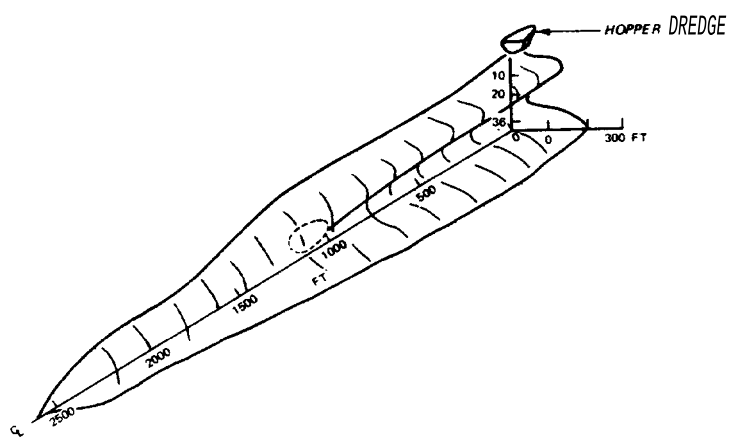


Figure 4-1. Hypothetical suspended solids plume downstream of a hopper dredge operation with overflow in San Francisco Bay (all distances in feet)*

several tens of parts per thousand (grams per litre) near the discharge port and as high as a few parts per thousand near the draghead. Turbidity levels in the near-surface plume appear to decrease exponentially with increasing distance from the dredge due to settling and dispersion, quickly reaching concentrations less than 1 ppt. However, plume concentrations may exceed background levels even at distances in excess of 4000 ft.

c. Bucket or Clamshell Dredge. The turbidity generated by a typical clamshell operation can be traced to sediment resuspension occurring when the bucket impacts on and is pulled off the bottom, turbid water spills out of the bucket or leaks through openings between the jaws, and material is inadvertently spilled during the barge loading operation. There is a great deal of variability in the amount of material resuspended by clamshell dredges due to variations in bucket size, operating conditions, sediment types, and hydrodynamic conditions at the dredging site. Based on limited measurements, it appears that, depending on current velocities, the turbidity plume downstream of a typical clamshell operation may extend approximately 1000 ft at the surface and 1600 ft near the bottom. Maximum concentrations of suspended solids in the surface plume should be less than 0.5 ppt in the immediate vicinity of the operation and decrease rapidly with distance from the operation due to settling and dilution of the material. Average water-column concentrations should generally be less than 0.1 ppt. The near-bottom plume will probably have a higher solids concentration, indicating that resuspension of bottom material near the clamshell impact point is probably the primary source of turbidity in the lower water column. The visible near-surface plume will probably dissipate rapidly within an hour or two after the operation ceases.

d. Cutterhead or Hydraulic Pipeline Dredge. Most of the turbidity generated by a cutterhead dredging operation is usually found in the vicinity of the cutter. The levels of turbidity are directly related to the type and quantity of material cut, but not picked up, by the suction. The ability of the dredge's suction to pick up bottom material determines the amount of cut material that remains on the bottom or suspended in the water column. In addition to the dredging equipment used and its mode of operation, turbidity may be caused by sloughing of material from the sides of vertical cuts; inefficient operational techniques; and the prop wash from the tenders (tugboats) used to move pipeline, anchors, etc., in the shallow water areas outside the channel. Based on limited field data collected under low current conditions, elevated levels of suspended material appear to be localized in the immediate vicinity of the cutter as the dredge swings back and forth across the dredging site. Within 10 ft of the cutter, suspended solids concentrations are highly variable but may be as high as a few tens of parts per thousand; these concentrations decrease exponentially from the cutter to the water surface. Near-bottom suspended solids concentrations may be elevated to levels of a few tenths of a part per thousand at distances of less than 1000 ft from the cutter.

Section III. Open-Water Disposal

4-5. Behavior of Discharges from Various Types of Dredges.

a. Hopper Dredge. The characterisitics and operation of hopper dredges are discussed in para 3-3 of this manual. When the hoppers have been filled as described, the dragarms are raised and the hopper dredge proceeds to the disposal site. At the disposal site, hopper doors in the bottom of the ship's hull are opened and the entire hopper contents are emptied in a matter of seconds; the dredge then returns to the dredging site to reload. This procedure produces a series of discrete discharges at intervals of perhaps one to several hours. Upon release from the hopper dredge at the disposal site, the dredged material falls through the water column as a well-defined jet of high-density fluid which may contain blocks of solid material. Ambient water is entrained during descent. After it hits bottom, some of the dredged material comes to rest. Some material enters the horizontally spreading bottom surge formed by the impact and is carried away from the impact point until the turbulence of the surge is sufficiently reduced to permit its deposition.

b. Bucket or Clamshell Dredge. Bucket dredges remove the sediment being dredged at nearly its *in situ* density and place it in barges or scows for transportation to the disposal area, as described in para 3-8. Although several barges may be used so that the dredging is essentially continuous, disposal occurs as a series of discrete discharges. The dredged material may be a slurry similar to that in a hopper dredge, but often sediments dredged by clamshell remain in fairly large consolidated clumps and reach the bottom in this form. Whatever its form, the dredged material descends rapidly through the water column to the bottom, and only a small amount of the material remains suspended.

c. Cutterhead or Hydraulic Pipeline Dredge. The operation of a cutterhead dredge, described in para 3-4, produces a slurry of sediment and water discharged at the disposal site in a continuous stream. As the dredge progresses up the channel, the pipeline is moved periodically to keep abreast of the dredge. The discharged dredged material slurry is generally dispersed in three modes. Any coarse material, such as gravel, clay balls, or coarse sand, will immediately settle to the bottom of the disposal area and usually accumulates directly beneath the discharge point. The vast majority of the fine-grained material in the slurry also descends rapidly to the bottom in a well-defined jet of high-density fluid, where it forms a low-gradient circular or elliptical fluid mud mound. Approximately 1 to 3 percent of the discharged material is stripped away from the outside of the slurry jet as it descends through the water column and remains suspended as a turbidity plume.

4-6. Dredged Material Dispersion at the Discharge Site.

a. Water-Column Turbidity. The levels of suspended solids in the water column around a discharge operation generally range from a few hundredths to a few tenths of a part per thousand. Concentrations are highest near the discharge point and rapidly decrease with increasing distance downstream from the discharge point and laterally away from the plume center line due to settling and horizontal dispersion of the suspended solids. Concentrations also decrease rapidly between each discrete hopper or barge discharge and after a pipeline is shut down or moved to a new location. Under tidal conditions, the plume will be subject to the tidal dynamics of the particular bay, estuary, or river mouth in which the dredging activity takes place. Many of the Corps projects have been studied in physical hydraulic models, and estimates of plume excursion can be made from their model reports. Rough estimates can be made from numerical models. Mathematical model result can be materially improved when calibrated by physical and/or prototype data; except under very simple conditions, all models have to be verified with prototype or prototype-derived data. In rivers where the flow is unidirectional, the plume length is controlled by the strength of the current and the settling properties of the suspended material. In both estuarine and riverine environments the natural levels of turbulence and the fluctuations in the rate of slurry discharge will usually cause the idealized teardrop-shaped plume to be distorted by gyres or eddylike patterns, as in figure 4-2.

b. Fluid Mud. A small percentage of the fine-grained dredged material slurry discharged during open-water disposal is dispersed in the water column as a turbidity plume; however, the vast majority rapidly descends to the bottom of the disposal area where it accumulates under the discharge point in the form of a low-gradient fluid mud mound overlying the existing bottom sediment, as shown in figure 4-3. If the discharge point of a hydraulic pipeline dredge is moved as the dredge advances, a series of mounds will develop. The majority of the mounded material is usually high-density (nonflowing) fluid mud that is covered by a surface layer of low-density (flowing or nonflowing) fluid mud. Under quiescent conditions, more than 98 percent of the sediment in the mudflow remains in the fluid mud layer at concentrations greater than 10 ppt, while the remaining 2 percent may be resuspended by mixing with the overlying water at the fluid mud surface. Fluid mud will tend to flow downhill as long as the bottom slope is approximately 1 percent or greater. A study of hopper dredge disposal at Carquinez Strait, San Francisco Bay, showed concentrations of dredged material in the water column were generally less than 0.2 ppt above background and persisted for only a few tens of minutes. However, 3 to 8 ft above the bottom, concentrations reached 20 ppt in a fluid mud layer. Similar occurrences of low suspended sediment concentrations in the water column with concentrations on the order of several tens of parts per thousand just above the bottom, as in figure 4-4, have been discussed for pipeline dredge discharges in WES TR DS-78-13. These conditions persist for the duration of the disposal operation at the site and for varying times thereafter as the material consolidates to typical sediment density.

c. Mounding. If bottom slopes are not great enough to maintain mudflows, the fluid mud will stop and begin to consolidate. When suspended sediment concentrations exceed 200 ppt the fluid mud can no longer flow freely but will accumulate around the discharge point in a low-gradient (e.g., 1:500) fluid mud mound. At the water column/fluid mud interface, the solids concentration increases very abruptly from perhaps a few tenths of a part per thousand in the water to approximately 200 ppt in the fluid

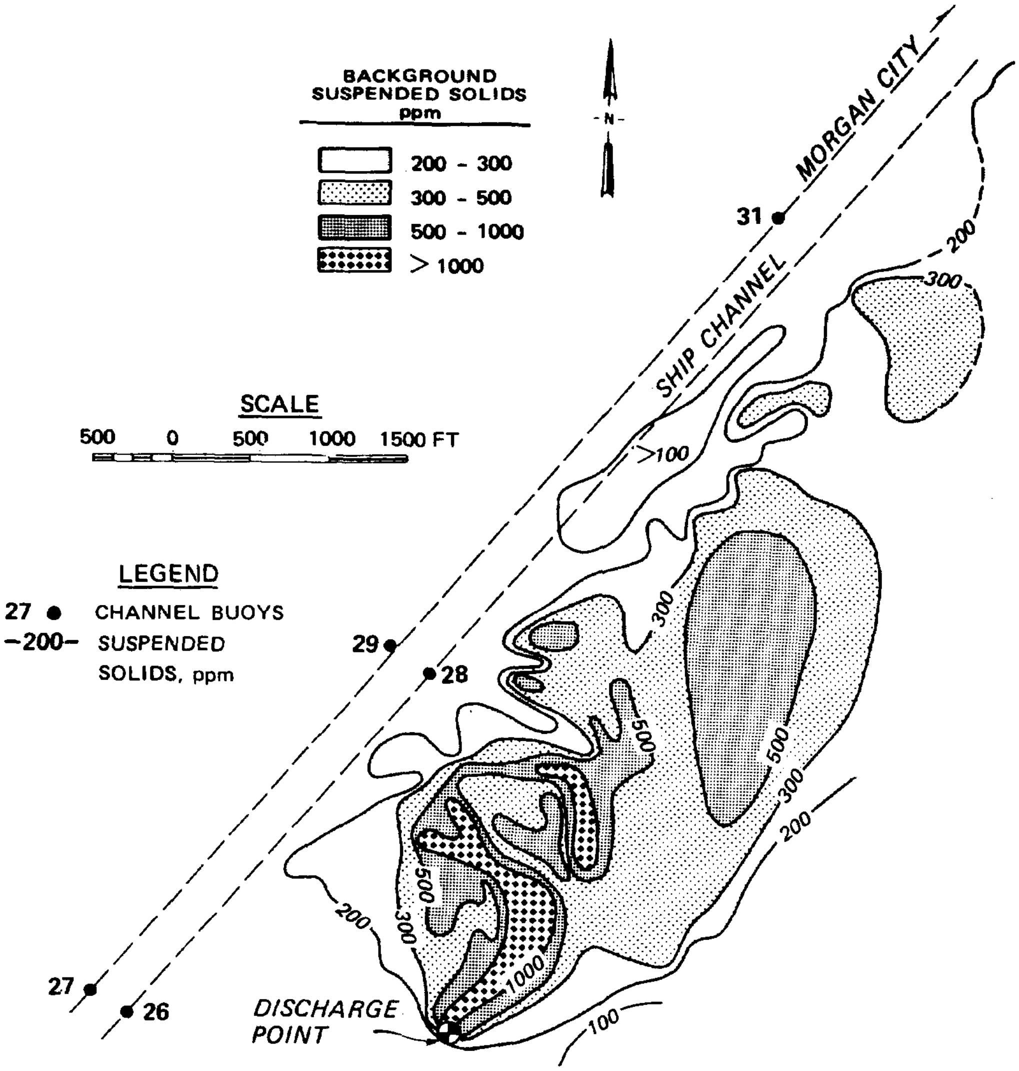


Figure 4-2. Middepth (3.0 ft) turbidity plume generated by a 28-in. pipeline disposal operation in the Atchafalaya Bay. Current flow is generally toward the northeast.

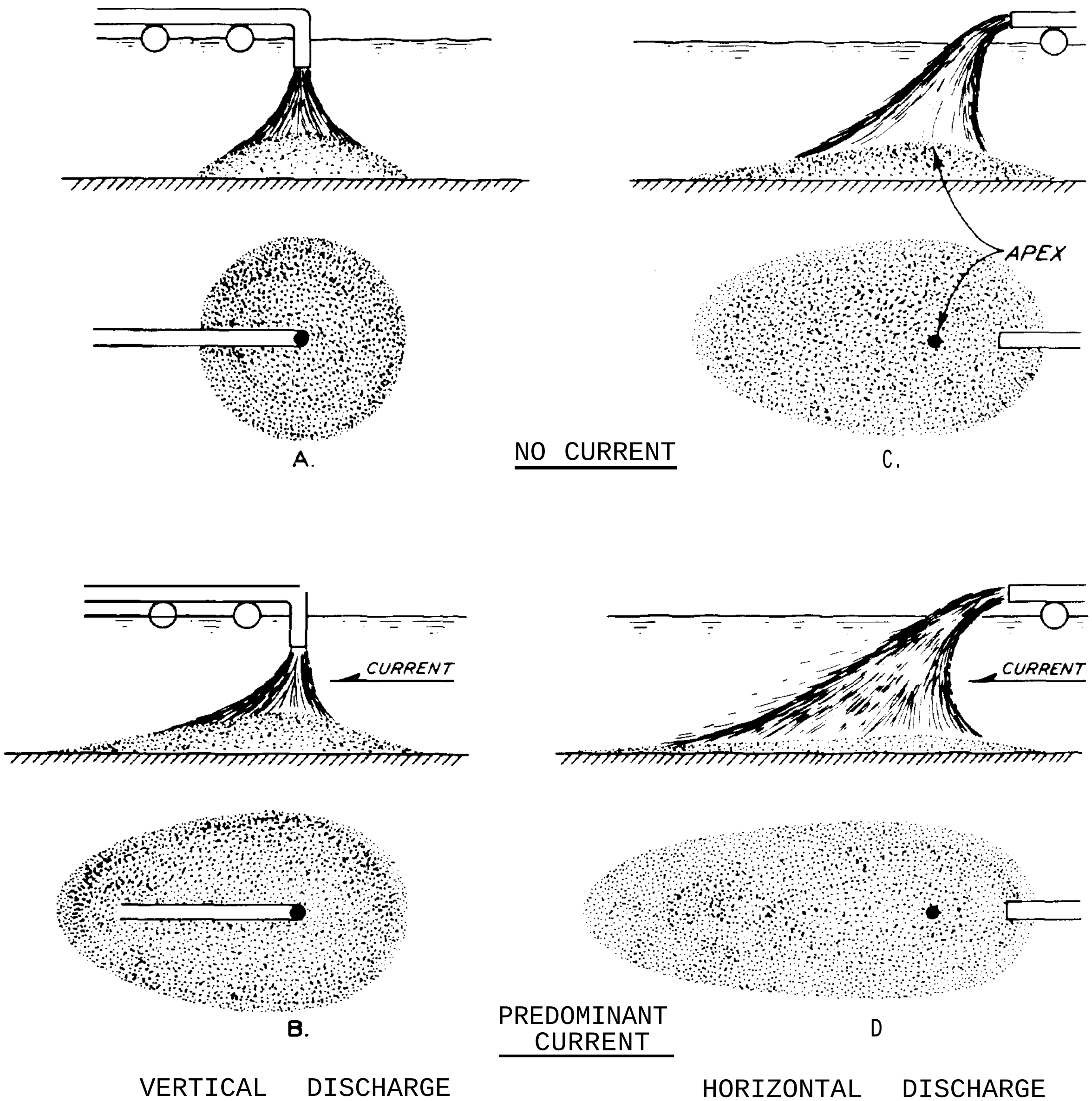


Figure 4-3. Effect of discharge angle and predominant current direction on the shape of a fluid mud mound.

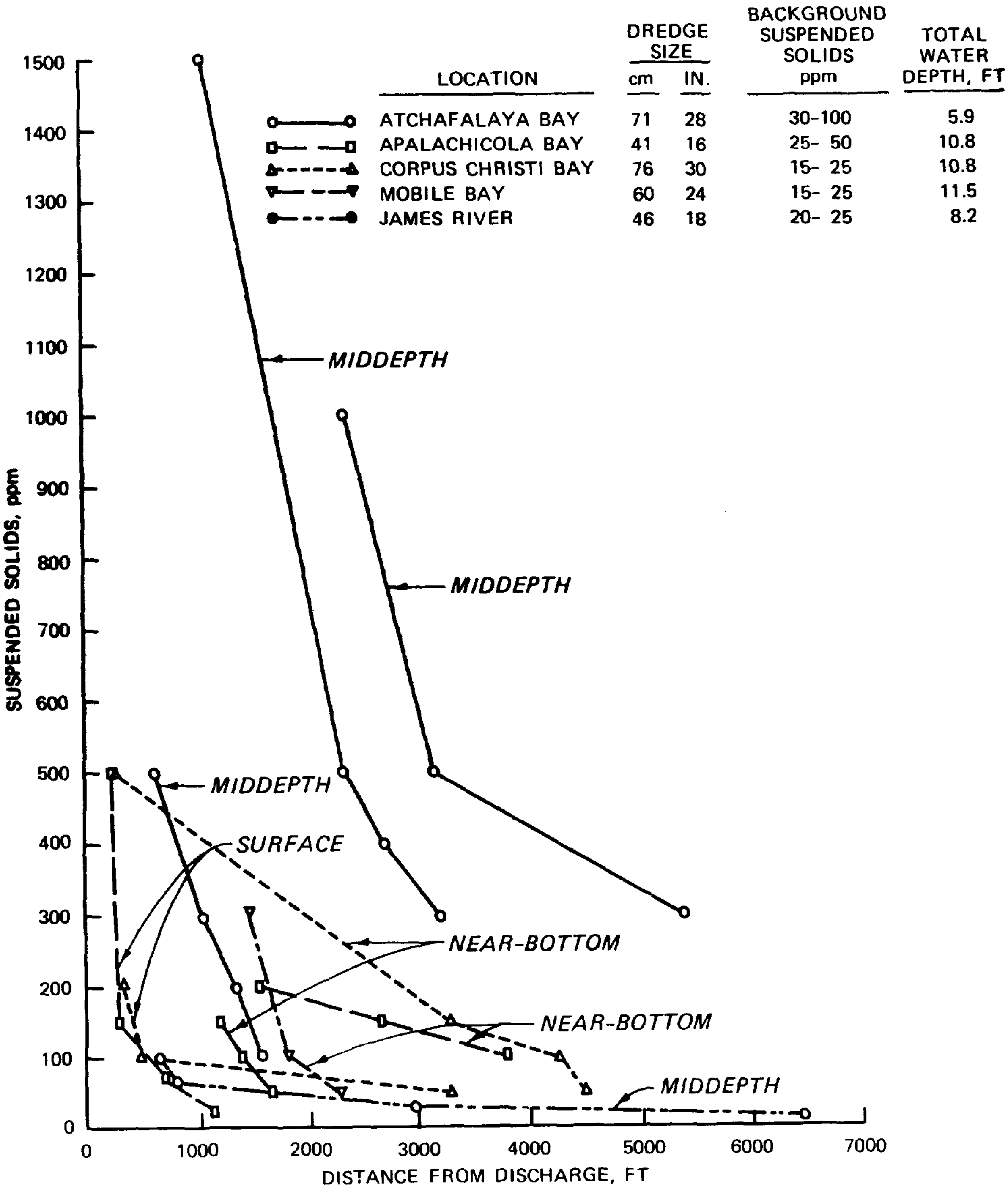


Figure 4-4. Relationship between suspended solids concentration along the plume center line and distance downcurrent from several open-water pipeline disposal operations measured at the indicated water depths,

mud. The solids concentration within the fluid mud increases above 200 ppt at a slower rate with depth until it reaches normal sediment densities. Deeper layers of fluid mud reach their final degree of consolidation more rapidly than thinner ones. Depending on the thickness of the fluid mud and its sedimentation/consolidation characteristics, complete consolidation of a fluid mud mound may require from one to several years. In those situations where material dredged by bucket or clamshell is of slurry consistency, the above description is generally applicable. More commonly, however, muddy sediments dredged by a clamshell remain in large clumps and descend to the bottom in this form. These may break apart somewhat on impact; but such material tends to accumulate in irregular mounds under the discharge vessel, rather than move outward from the discharge point. Whatever the dredging method, sandy sediments tend to mound directly beneath the discharge pipe or vessel.

d. Special Circumstances. Knowledge of the behavior of discharged dredged material allows control of the dispersion of the material at the disposal site. When minimum dispersal is desired, the dredged material can be discharged into old underwater borrow pits, sand or gravel excavation sites, etc. Such deposits may be further isolated from the overlying water column by covering with a layer of uncontaminated sediment. It is also possible to place such a covering, or "cap," over dredged material discharged onto a flat bottom.

4-7. Environmental Impacts in the Water Column.

a. Contaminants. Although the vast majority of heavy metals, nutrients, and petroleum and chlorinated hydrocarbons are usually associated with the fine-grained and organic components of the sediment (see WES TR DS-78-4), there is no biologically significant release of these chemical consituents from typical dredged material to the water column during or after dredging or disposal operations. Levels of manganese, iron, ammonium nitrogen, orthophosphate, and reactive silica in the water column may be increased somewhat for a matter of minutes over background conditions during open-water disposal operations; however, there are no persistent well-defined plumes of dissolved metals or nutrients at levels significantly greater than background concentrations.

b. Turbidity. There are now ample research results indicating that the traditional fears of water-quality degradation resulting from the resuspension of dredged material during dredging and disposal operations are for the most part unfounded. The possible impact of depressed levels of dissolved oxygen has also been of some concern, due to the very high oxygen demand associated with fine-grained dredged material slurry. However, even at open-water pipeline disposal operations where the dissolved oxygen decrease should theoretically be greatest, near-surface dissolved oxygen levels of 8 to 9 ppm will be depressed during the operation by only 2 to 3 ppm at distances of 75 to 150 ft from the discharge point. The degree of oxygen depletion generally increases with depth and increasing concentration of total suspended solids; near-bottom levels may be less than 2 ppm. However, dissolved oxygen levels usually increase with increasing distance from the discharge point, due to dilution and settling of the suspended material.

(1) It has been demonstrated that elevated suspended solids concentrations are generally confined to the immediate vicinity of the dredge or discharge point and dissipate rapidly at the completion of the operation. If turbidity is used as a basis for evaluating the environmental impact of a dredging or disposal operation, it is essential that the predicted turbidity levels are evaluated in light of background conditions. Average turbidity levels, as well as the occasional relatively high levels that are often associated with naturally occurring storms, high wave conditions, and floods, should be considered.

(2) Other activities of man may also be responsible for generating as much or more turbidity than dredging and disposal operations. For example, each year shrimp trawlers in Corpus Christi Bay, Texas, suspend 16 to 131 times the amount of sediment that is dredged annually from the main ship channel. In addition, suspended solids levels of 0.1 to 0.5 ppt generated behind the trawlers are comparable to those levels measured in the turbidity plumes around open-water pipeline disposal operations. Resuspension of bottom sediment in the wake of large ships, tugboats, and tows can also be considerable. In fact, where bottom clearance is 3 ft or less, there may be scour to a depth of 3 ft if the sediment is easily resuspended.

4-8. Environmental Impacts on the Benthos.

a. Physical. Whereas the impact associated with water-column turbidity around dredging and disposal operations is for the most part insignificant, the dispersal of fluid mud dredged material appears to have a relatively significant short-term impact on the benthic organisms within open-water disposal areas. Open-water pipeline disposal of fine-grained dredged material slurry may result in a substantial reduction in the average abundance of organisms and a decrease in the community diversity in the area covered by fluid mud. Despite this immediate impact, recovery of the community apparently begins soon after the disposal operation ceases.

(1) Disposal operations will blanket established bottom communities at the site with dredged material which may or may not resemble bottom sediments at the disposal site. Recolonization of animals on the new substrate and the vertical migration of benthic organisms in newly deposited sediments can be important recovery mechanisms. The first organisms to recolonize dredged material usually are not the same as those which had originally occupied the site; they consist of opportunistic species whose environmental requirements are flexible enough to allow them to occupy the disturbed areas. Trends toward reestablishment of the original community are often noted within several months of disturbance, and complete recovery approached within a year or two. The general recolonization pattern is often dependent upon the nature of the adjacent undisturbed community, which provides a pool of replacement organisms capable of recolonizing the site by adult migration or larval recruitment.

(2) Organisms have various capabilities for moving upward through newly deposited sediments, such as dredged material, to reoccupy positions relative to the sediment-water interface similar to those maintained prior to burial by the disposal activity. Vertical migration ability is greatest in dredged material similar to that in which the animals normally occur and is minimal in sediments of dissimilar particle-size distribution. Bottom-dwelling organisms having morphological and physiological adaptations for crawling through sediments are able to migrate vertically through several inches of overlying sediment. However, physiological status and environmental variables are of great importance to vertical migration ability. Organisms of similar life-style and morphology react similarly when covered with an overburden. For example, most surface-dwelling forms are generally killed if trapped under dredged material overburdens, while subsurface dwellers migrate to varying degrees. Laboratory studies suggest vertical migration may very well occur at disposal sites, although field evidence is not available. Literature review (WES TR DS-78-1) indicates the vertical migration phenomenon is highly variable among species.

(3) Dredging and disposal operations have immediate localized effects on the bottom life. The recovery of the affected sites occurs over periods of weeks, months, or years, depending on the type of environment and the biology of the animals and plants affected. The more naturally variable the physical environment, especially in relation to shifting substrate due to waves or currents, the less effect dredging and disposal will have. Animals and plants common to such areas of unstable sediments are adapted to physically stressful conditions and have life cycles which allow them to withstand the stresses imposed by dredging and disposal. Exotic sediments (those in or on which the species in question does not normally live) are likely to have more severe effects when organisms are buried than sediments similar to those of the disposal site. Generally, physical impacts are minimized when sand is placed on a sandy bottom and are maximized when mud is deposited over a sand bottom. When disposed sediments are dissimilar to bottom sediments at the sites, recolonization of the dredged material will probably be slow and carried out by organisms whose life habits are adapted to the new sediment. The new community may be different from that originally occurring at the site.

(4) Dredged material discharged at disposal sites which have a naturally unstable or shifting substrate due to wave or current action is rather quickly dispersed and does not cover the area to substantial depths. This natural dispersion, which usually occurs most rapidly and effectively during the stormy winter season, can be assisted by conducting the disposal operation so as to maximize the spread of dredged material, producing the thinnest possible overburden. The thinner the layer of overburden, the easier it is for mobile organisms to survive burial by vertical migration through dredged material. The desirability of minimizing physical impacts by dispersion can be overridden by other considerations, however. For example, dredged material shown by biological or chemical testing to have a potential for adverse environmental impacts might best be placed in an area of retention, rather than dispersion. This would maximize habitat disruption in a restricted area, but would confine potentially more important chemical impacts to tha same small area.

(5) Since larval recruitment and migration of adults are primary mechanisms of recolonization, recovery from physical impacts will generally be most rapid if disposal operations are completed shortly before the seasonal increase in biological activity and larval abundance in the area. The possibility of impacts can also be reduced by locating disposal sites in the least sensitive or critical habitats. This can sometimes be done on a seasonal basis. Known fish migratory routes and spawning beds should be avoided just before and during use, but might be acceptable for disposal during other periods of the year. However, care must be taken to ensure that the area returns to an acceptable condition before the next intensive use by the fish. Clam or oyster beds, municipal or industrial water intakes, highly productive backwater areas, etc., should be avoided in selecting disposal sites.

(6) All the above factors should be evaluated in selecting a disposal site, method, and season in order to minimize the habitat disruption of disposal operations. All require evaluations on a case-by-case basis by persons familiar with the ecological principles involved, as well as the characteristics of the proposed disposal operations and the local environment.

b. <u>Contaminants</u>.

(1) Dredging and disposal do not introduce new contaminants to the aquatic environment, but simply redistribute the sediments which are the natural depository of contaminants introduced from other sources. The potential for accumulation of a metal in the tissues of an organism (bioaccumulation) may be affected by several factors such as duration of exposure, salinity, water hardness, exposure concentration, temperature, the chemical form of the metal, and the particular organism under study. The relative importance of these factors varies from metal to metal, but there is a trend toward greater uptake at lower salinities. Elevated concentrations of heavy metals in tissues of benthic invertebrates are not always indicative of high levels of metals in the ambient medium or associated sediments. Although a few instances of uptake of possible ecological significance have been shown, the diversity of results among species, different metals, types of exposure, and salinity regimes strongly argues that bulk analysis of sediments for metal content cannot be used as a reliable index of metal availability and potential ecological impact of dredged material, but only as an indicator of total metal context. Bioaccumulation of most metals from sediments is generally minor. Levels often vary from one sample period to another and are quantitatively marginal, usually being less than one order of magnitude greater than levels in the control organisms, even after one month of exposure. Animals in undisturbed environments may naturally have high and fluctuating metal levels. Therefore, in order to evaluate bioaccumulation, comparisons should be made between control and experimental organisms at the same point in time.

(2) Organochlorine compounds such as DDT, dieldrin, and polychlorinated biphenyls (PCB's) are environmental contaminants of worldwide significance which are manmade and, therefore, do not exist naturally in the earth's crust. Organochlorine compounds are generally not soluble in surface waters at concentrations higher than approximately 20 ppb, and most of

the amount present in waterways is associated with either biological organisms or suspended solids. Organochlorine compounds are released from sediment until some equilibrium concentration is achieved between the aqueous and the solid phases and then readsorbed by other suspended solids or biological organisms in the water column. The concentration of organochlorines in the water column is reduced to background levels within a matter of hours as the organochlorine compounds not taken up by aquatic organisms eventually settle with the particulate matter and become incorporated into the bottom deposits in aquatic ecosystems. Most of these compounds are stable and may accumulate to relatively high concentrations in the sediments. The manufacture and/or disposal of most of these compounds is now severely limited; however, sediments that have already been contaminated with organochlorine compounds will probably continue to have elevated levels of these compounds for several decades. The low concentrations of chlorinated hydrocarbons in sediment interstitial water indicate that during dredging operations, the release of the interstitial water and contaminants to the surrounding environment would not create environmental problems. Bioaccumulation of chlorinated hydrocarbons from deposited sediments does occur. However, the sediments greatly reduce the bioavailability of these contaminants, and tissue concentrations may range from less than one to several times the sediment concentration. Unreasonable degradation of the aquatic environment due to the routine maintenance dredging and disposal of sediment contaminated with chlorinated hydrocarbons has never been demonstrated.

(3) The term “oil and grease” is used collectively to describe all components of sediments of natural and contaminant origin which are primarily fat soluble. There is a broad variety of possible oil and grease components in sediment, the analytical quantification of which is dependent on the type of solvent and method used to extract these residues. Trace contaminants, such as PCB’s and chlorinated hydrocarbons, often occur in the oil and grease’. Large amounts of contaminant oil and grease find their way into the sediments of the Nation’s waterways either by spillage or as chronic inputs in municipal and industrial effluents, particularly near urban areas with major waste outfalls. The literature suggests long-term retention of oil and grease residues in sediments, with minor biodegradation occurring. Where oily residues of known toxicity became associated with sediments, these sediments retained toxic properties over periods of years, affecting local biota. Spilled oils are known to readily become adsorbed to naturally occurring suspended particulates, and oil residues in municipal and industrial effluents are commonly found adsorbed to particles. These particulates are deposited in sediments and are subject to suspension during disposal. Even so, there is only slight desorption, and the amount of oil released during the elutriate test is less than 0.01 percent of the sediment-associated hydrocarbons under worst-case conditions. Selected estuarine and freshwater organisms exposed for periods up to 30 days to dredged material that is contaminated with thousands of parts per million of oil and grease experience minor mortality. Uptake of hydrocarbons from heavily contaminated sediments appears minor when compared with the hydrocarbon content of the test sediments.

(4) Ammonia is one of the potentially toxic materials known to be released from sediments during disposal; it is routinely found in evaluations

of sediments using the elutriate test and in the water near a disposal area where concentrations rapidly return to baseline levels. Similar temporary increases in ammonia at marine, estuarine, and freshwater disposal sites have been documented in several DMRP field studies, but concentrations and durations are usually well below levels causing concern.

(5) The potential environmental impact of contaminants associated with sediments must be evaluated in light of chemical and biological data describing the availability of contaminants to organisms. Information must then be gained as to the effects of specific substances on organism survival and function. Many contaminants are not readily released from sediment attachment and are thus less toxic than contaminants in the free or soluble state on which most toxicity data are based.

(6) There are now cogent reasons for rejecting many of the conceptualized impacts of disposed dredged material based on classical bulk analysis determinations. It is invalid to use total sediment concentration to estimate contaminant levels in organisms since only a variable and undetermined amount of sediment-associated contaminant is biologically available. Although a few instances of toxicity and bioaccumulation of possible ecological consequence have been seen, the fact that the degree of effect depends on species, contaminants, salinity, sediment type, etc., argues strongly that bulk analysis does not provide a reliable index of contaminant availability and potential ecological impact of dredged material.

4-9. <u>Overview of Open-Water Disposal</u>.

a. Prediction of physical effects of dredging and disposal is fairly straightforward. Physical effects include removal of organisms at dredging sites and burial of organisms at disposal sites. Physical effects are restricted to the immediate areas of dredging or disposal. Recolonization of sites occurs in periods of months to 1-2 years in case studies. Disturbed sites may be recolonized by opportunistic species which are not normally the dominant species occurring at the site.

b. Many organisms are very resistant to the effects of sediment suspensions in the water; aside from natural systems requiring clear water, such as coral reefs and some aquatic plant beds, dredging or disposal-induced turbidity is not of major ecological concern. The formation of fluid muds due to disposal is not fully understood and is of probable environmental concern in some situations.

c. Release of sediment-associated heavy metals and chlorinated hydrocarbons to the water column by dredging and disposal has been found to be the exception, rather than the rule. Metals are rarely bioaccumulated from sediments and then only to low levels. Chlorinated hydrocarbons may be bioaccumulated from sediments, but only very highly contaminated sediments might result in tissue concentrations of potential concern. There is little or no correlation between bulk analysis of sediments for contaminants and their environmental impact.

d. Oil and grease residues, like heavy metals, are tightly bound to sediment particles, and there appears to be minimal uptake of the residues into organism tissues. Of the thousands of chemicals constituting the oil and grease fraction, very few can be considered significant threats to aquatic life when associated with dredged material.

e. Many laboratory studies describe worst-case experimental conditions where relatively short-term exposures to high concentrations of sediments and contaminants are investigated. Although limited in scope, experimental results showing the lack of effects under these worst-case conditions support the conclusion that the indirect long-term and sublethal effects of dredging and disposal will be minimal. An integrated, whole-sediment bioassay using sensitive test organisms should be used to determine potential sediment impacts at a particular site. Appropriate chemical testing and biological evaluation of the dredged material can be used to resolve any site-specific problems which may occur.

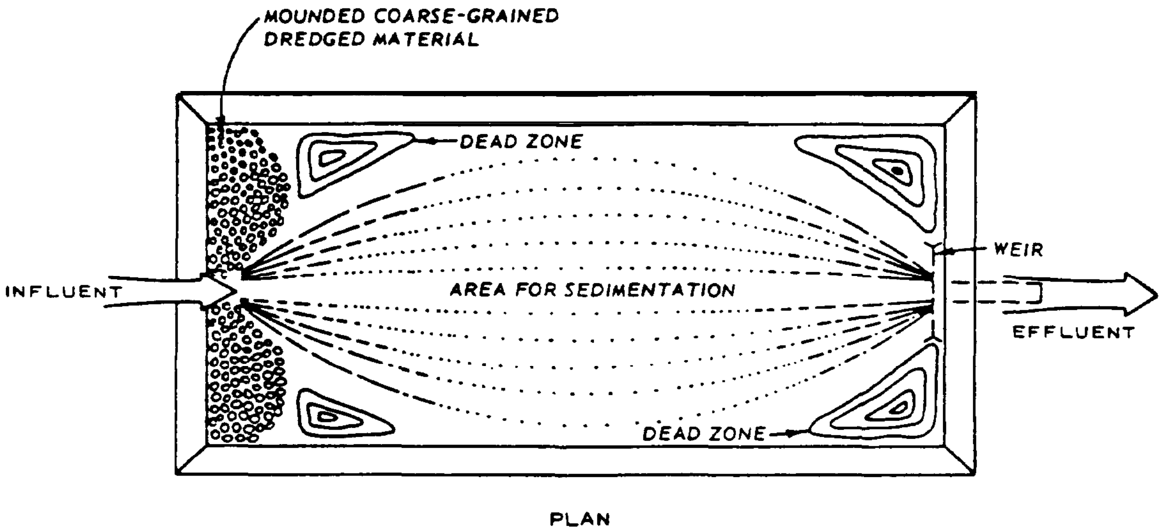
Section IV. Confined Dredged Material Disposal

4-10. Containment Area Design.

a. Concepts of Containment Area Operation.

(1) Diked containment areas are used to retain dredged material solids while allowing the carrier water to be released from the containment area. The two objectives of a containment area are: (a) to provide adequate storage capacity to meet dredging requirements and (b) to attain the highest possible efficiency in retaining solids during the dredging operation in order to meet effluent suspended solids requirements. These considerations are interrelated and depend upon effective design, operation, and management of the containment area. Major considerations in design of containment areas are discussed below. Detailed design guidance may be found in WES TR DS-78-10.

(2) The major components of a dredged material containment area are shown schematically in figure 4-5. A tract of land is surrounded by dikes to form a confined surface area into which dredged channel sediments are pumped hydraulically. In some dredging operations, especially in the case of new work dredging, sand, clay balls, and/or gravel may be present. Thi coarse material rapidly falls out of suspension and forms a mound near the dredge inlet pipe. The fine-grained material (silt and clay) continues to flow through the containment area where most of the solids settle out of suspension and thereby occupy a given storage volume. The fine-grained dredged material is usually rather homogeneous and is easily characterized The clarified water is discharged from the containment area over a weir. This effluent can be characterized by its suspended solids concentration and rate of outflow. Effluent flow rate is approximately equal to influent flow rate for continuously operating disposal areas. To promote effective sedimentation, ponded water is maintained in the area; the depth of water is controlled by the elevation of the weir crest. The thickness of the dredged material layer increases with time until the dredging operation is completed. Minimum freeboard requirements and mounding of coarse-grained



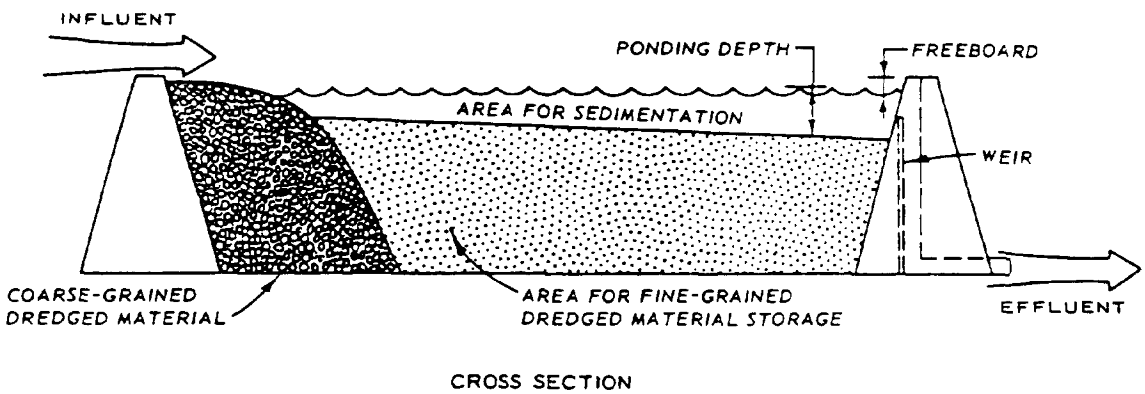


Figure 4-5. Schematic diagram of a dredged material containment area,

material result in a ponded surface area smaller than the total surface area enclosed by the dikes. In most cases, confined disposal areas must be utilized over a period of many years, storing material dredged periodically over the design life. Long-term storage capacity for these sites is influenced by consolidation of dredged material and foundation soils, dewatering of material, and effective management of the disposal area.

b. Evaluation of Dredging Activities. Effective planning and design of containment areas first requires a thorough evaluation of the dredging program. The location, volumes, frequencies, and types of material to be dredged must be estimated. The number, types, and sizes of dredges normally employed to do the work should also be considered. This information is important for defining project objectives and provides a basis for containment area design.

c. Field Investigations.

(1) Samples of the channel sediments to be dredged are required for adequate characterization of the material and for use in sedimentation and consolidation testing. The level of effort required for channel sediment sampling depends upon the project. In the case of routine maintenance work, data from prior samplings and experience with similar material may be available to reduce the scope of field investigations. Since maintenance sediments are in an essentially unconsolidated state, grab samples are normally satisfactory for sediment characterization purposes and are easy and inexpensive to obtain. For unusual maintenance projects or new work, more extensive field investigations will be required.

(2) Field investigations must also be performed at the containment area site to define foundation conditions and to obtain samples for laboratory testing if estimates of long-term storage capacity are required. The extent of required field investigations is dependent upon project size and upon foundation conditions at the site. It is particularly important to define foundation conditions, including depth, thickness, extent, and composition of foundation strata, and to obtain undisturbed samples of compressible foundation soils and any previously placed dredged material. If possible, the field investigations required for estimating long-term storage capacity should be planned and accomplished along with those required for the engineering design of the retaining dikes.

d. Laboratory Testing.

(1) Laboratory tests are required primarily to provide data for sediment characterization, containment area design, retention dike design, and long-term storage capacity estimates. The laboratory tests and procedures required are essentially standard tests and generally follow accepted procedures. The required magnitude of the laboratory testing program depends upon the project. Fewer tests are usually required when dealing with a relatively homogeneous material and/or when data are available from previous tests and experience, as is frequently the case in maintenance work. For unusual maintenance projects where considerable variation in sediment properties is apparent from samples, or for new work projects, more extensive laboratory testing programs are required. Refer to WES TR DS-78-10 for details on testing procedures.

(2) Sedimentation tests, performed in 8-in.-diameter ported columns as shown in figure 4-6, are necessary to provide design data for retention of suspended solids (item 4). These tests are designed to define the flocculent or zone-settling behavior of a particular sediment and to provide information concerning the volumes occupied by newly placed layers of dredged material. Sedimentation of freshwater sediments at slurry concentrations of less than 100 ppt can generally be characterized by flocculent settling properties. As slurry concentrations are increased, the sedimentation process may be characterized by zone-settling properties. Salinity greater than 3 ppt enhances the flocculation of dredged material particles; therefore, the settling properties of saltwater dredged material can usually be characterized by zone-settling tests. The flocculent settling test

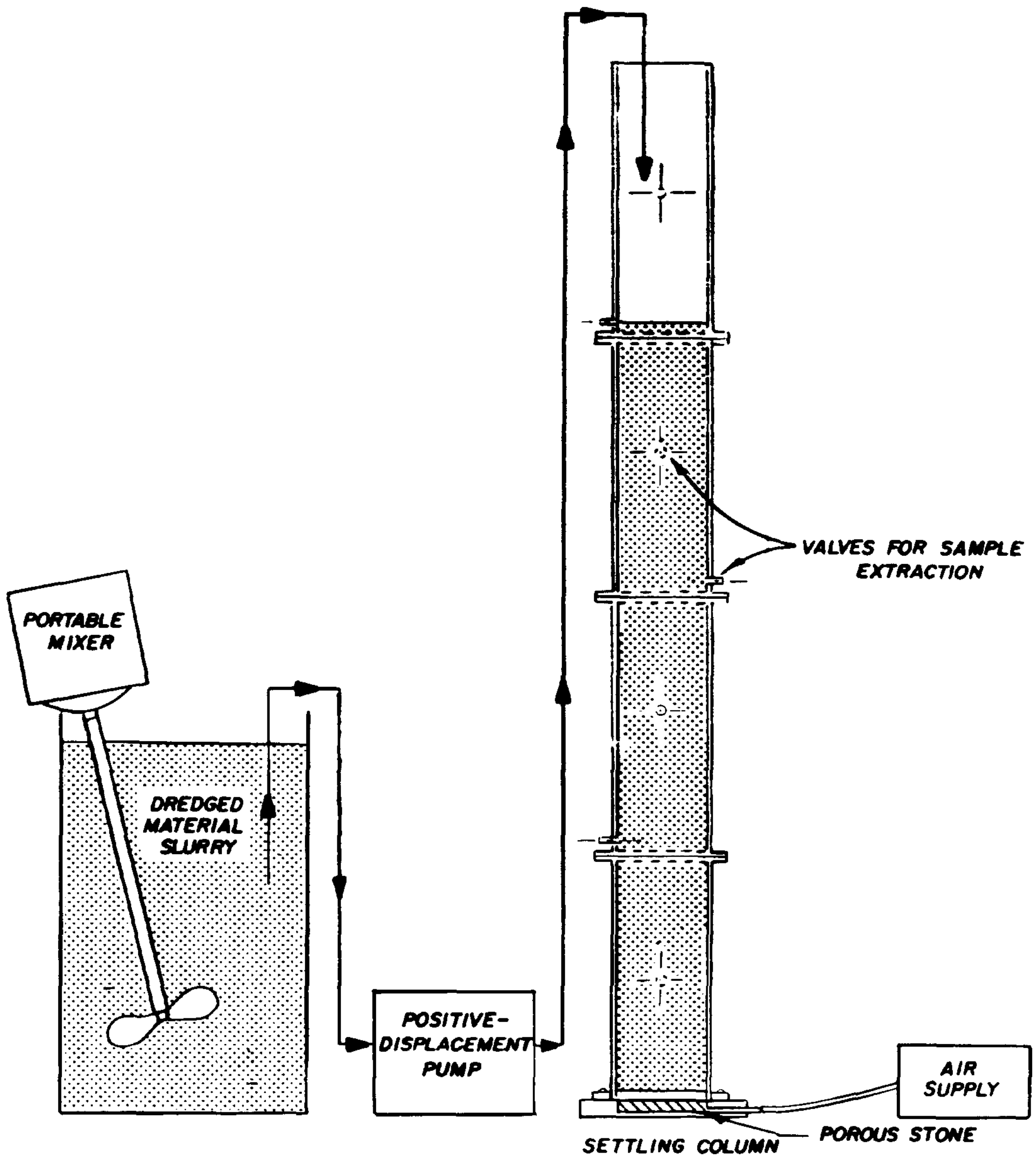


Figure 4-6. Schematic of apparatus for settling tests.

consists of measuring the concentration of suspended solids at various depths and time intervals by withdrawing samples from the settling column ports. The zone-settling test consists of placing a slurry in a settling column and timing the fall of the liquid-solids interface.

(3) Determination of containment area long-term storage capacity requires estimates of settlement due to self-weight consolidation of newly placed dredged material and due to consolidation of compressible foundation soils. Consolidation test results, including time-consolidation data, must therefore be obtained. Consolidation tests for foundation soils should be

performed as described in EM 1110-2-1906 with no modifications. The consolidation testing procedure for sediment samples generally follows that for the fixed ring test for conventional soils, but minor modifications in sample preparation and loading are required (WES TR DS-78-10).

e. Design for Retention of Suspended Solids.

(1) Sedimentation, as applied to dredged material disposal activities, refers to those operations in which the dredged material slurry is separated into more clarified water and a more concentrated slurry. Laboratory sedimentation tests must provide data for designing the containment area to meet effluent suspended solids criteria and to provide adequate storage capacity for the dredged solids. These tests are based on the gravity separation of solid particles from the transporting water.

(2) The sedimentation process can be categorized according to three basic classifications:

(a) Discrete settling. The particle maintains its individuality and does not change in size, shape, or density during the settling process.

(b) Flocculent settling. Particles agglomerate during the settling period with a change in physical properties and settling rate.

(c) Zone settling. The flocculent suspension forms a lattice structure and settles as a mass, exhibiting a distinct interface during the settling process.

(3) The important factors governing the sedimentation of dredged material solids are the initial concentration of the slurry and the flocculating properties of the solid particles. Montgomery (item 4) demonstrated by experiments that, because of the high influent solids concentration and the tendency of dredged material fine-grained particles to flocculate, either flocculate or zone-settling behavior governs sedimentation in containment areas. Discrete settling describes the sedimentation of sand particles and fine-grained sediments at concentrations much lower than those found in dredged material containment areas. Test results using the 8-in.-diameter settling column are used to design the containment area for solids retention based on principles of flocculent or zone settling. Detailed design procedures found in WES TR DS-78-10 will determine surface area, containment area volume, ponding depth, and freeboard requirements. The designs must consider the hydraulic efficiency of the containment, based on shape and topography, and the proper sizing of outlet structures.

f. Evaluation of Long-Term Storage Capacity.

(1) If the containment area is intended for one-time use, as is the case in some new work projects, estimates of long-term storage capacity are not required. However, containment areas intended for use in recurring maintenance work must be sized for long-term storage capacity over the service life of the facility. Storage capacity is defined as the total volume available to hold additional dredged material and is equal to the total

unoccupied volume minus the volume associated with ponding and freeboard requirements.

(2) The following factors must be considered in estimating long-term containment area storage capacity:

(a) After dredged material is placed within a containment area, it undergoes sedimentation and self-weight consolidation resulting in gains in storage capacity.

(b) The placement of dredged material imposes a loading on the containment area foundation, and additional settlement may result due to consolidation of compressible foundation soils.

(c) Since the consolidation process is slow, especially in the case of fine-grained materials, it is likely that total settlement will not have taken place before space in the containment area is required for additional placement of dredged material. For this reason, the time-consolidation relationship is an important consideration.

(d) Settlement of the containing dikes significantly affects the available storage capacity.

(3) Estimation of gains in long-term capacity can be made using results of laboratory consolidation tests and application of fundamental principles of consolidation modified to consider the self-weight consolidation behavior of newly placed dredged material. Detailed procedures for estimating long-term storage capacity are found in WES TR DS-78-10.

g. Weir Design. The purpose of the weir structure is to regulate release of ponded water from the containment area. Proper weir design and operation can control resuspension and withdrawal of settled solids. This is possible only if the containment areas have been properly designed to provide sufficient area and volume for sedimentation. Weirs are designed to provide selective withdrawal of the clarified upper layer of ponded water. In order to maintain acceptable effluent quality, the upper water layers containing low levels of suspended solids should be ponded at depths greater than the depth of the withdrawal zone; i.e., the area through which fluid is removed for discharge over the weir. The size of the withdrawal zone as determined by the weir loaction and configuration affects the velocity of flow toward the weir. Detailed considerations in weir design and design nomographs for determining required weir crest lengths are found in WES TR DS-78-10. Weirs should be structurally designed to withstand anticipated loadings at maximum ponding elevations, with consideration given to uplift forces and potential piping beneath or around the wier. Outlet pipes for the weir structure must be designed to carry flows in excess of the flow rate for the largest dredge size expected to provide for emergency release of ponded waters.

h. Chemical Clarification for Reduction of Effluent Suspended Solids.

(1) When dredged material slurry is disposed in a well-designed, well-managed containment area, the vast majority of the solids will settle out of suspension and be retained within the settling basin. However, gravity sedimentation alone will not remove all suspended solids. Any fine-grained material suspended in the ponded water above the settled solids will be discharged in the effluent water. In addition, the levels of chemical constituents in the effluent water are directly related to the amount of suspended fine-grained material; therefore, retention of fine-grained solids in the containment area results in a maximum degree of retention of potentially toxic chemical constituents. Effluent standards may require removal of suspended solids over and above that attained by gravity sedimentation.

(2) In the absence of a fully engineered treatment system, several expedient measures can be employed to enhance retention of the suspended solids within a containment area of a given size before effluent discharge. They include: intermittent pumping, increasing the depth of ponded water, increasing the effective length of the weir, temporarily discontinuing operations, or decreasing the size of the dredge.

(3) Flocculation. One method specifically for reducing the levels of fine-grained (clay-sized) suspended solids levels in the effluent involves treating the containment area effluent or the dredged material slurry with chemical flocculants to encourage the formation of flocs (i.e., particle agglomerates) that settle more rapidly than individual particles. This agglomeration or coagulation process is accomplished by an alteration of the electrochemical properties of the clay particles and the bridging of particles and small flocs by long polymer chains. Because of the large number of manufacturers of polyelectrolytes and the types available, preliminary screening of flocculants is necessary. Evaluation and determination of the optimum dose of several nontoxic polymers may be accomplished using jar-testing procedures. These procedures will indicate the most cost-effective polymer and the optimum dosage of the polymer solution for treating the suspended solids levels, as well as the optimum mixing intensities and durations for both rapid- and slow-mixing stages. Optimum detention times and surface overflow rates for clarifying the flocced suspensions and a general indication of the volume of flocced material that must be stored or re-handled can be determined from settling tests. Schroeder (item 8) presents design guidance for the use of chemical clarification methods.

i. Dike Design. Dikes for retaining or confining dredged material are normally earthen embankments similar to flood protection levees. Dike locations are usually determined by land available-for disposal areas; therefore, dikes sometimes must be constructed in areas of poor foundation quality and from materials of poor construction quality. In past years, retaining dikes for dredged material have been designed and constructed with less effort and expense than other engineered structures. The potential for dike failures and the environmental and economic damage which can result dictate that retaining dikes be properly designed and constructed using the principles of geotechnical engineering. Foundation investigations and laboratory soils tests and analyses must be conducted to design dikes to the desired degree of safety against failures. Procedures used in dike design generally parallel those required for design of flood protection levees or earth-filled dams. WBS TR D-77-9 contains detailed guidelines for the design and construction of retaining dikes.

4-11. Containment Area Operation and Management.

a. Containment Area Operation. A major consideration in proper containment area operation is providing the ponding necessary for sedimentation and retention of suspended solids. Adequate ponding depth during the dredging operation is maintained by controlling the weir crest elevation, usually by placing boards within the weir structure. Before dredging commences, the weir should be boarded to the highest possible elevation that dike stability considerations will allow. This practice will ensure maximum possible efficiency of the containment area. The maximum elevation must allow for adequate ponding depth above the highest expected level of accumulated settled solids and yet remain below the required freeboard. If the basin is undersized or if inefficient settling is occurring in the basin, it is necessary to increase detention time and reduce approach velocity to achieve efficient settling and to avoid resuspension, respectively. Detention time can be increased by raising the weir crest to its highest elevation to increase the ponding depth; or it may be increased by operating the dredge intermittently to maintain a maximum allowable static head or depth of flow over the weir, based on the effluent quality achieved at various weir crest elevations. Once the dredging operation is completed, the ponded water must be removed to promote drying and consolidation of dredged material. Refer to WES TR DS-78-10.

b. Containment Area Management.

(1) Periodic site inspections. The importance of periodic site inspections and continuous site management following the dredging operation cannot be overemphasized. Once the dredging operation has been completed and the ponded water has been decanted, site management efforts should be concentrated on maximizing the containment storage capacity gained from continued drying and consolidation of dredged material and foundation soils. To ensure that precipitation does not pond water, the weir crest elevation must be kept at levels allowing efficient release of runoff water. This will require periodic lowering of the weir crest elevation as the dredged material surface settles.

(2) Thin-lift placement. Gains in long-term storage capacity of containment areas through natural drying processes can also be increased by placing the dredged material in thin lifts. Thin-lift placement greatly increases potential capacity through active dewatering and disposal area reuse management programs. Thin-lift placement can be achieved by obtaining sufficient land area to ensure adequate storage capacity without the need for thick lifts. It requires careful long-range planning to ensure that the large land *area* is used effectively for dredged material dewatering, rather than simply being a containment area whose service life is longer than that of a smaller area. Dividing a large containment area into several compartments can facilitate management; each compartment can be managed separately so that some compartments are being filled while the

dredged material in others is being dewatered. One possible management scheme for large compartmentalized containments is shown conceptually in figure 4-7. For this operation, thin lifts of dredged material are placed into each compartment in the following sequence: filling, settling and surface drainage, dewatering, and dike raising (using dewatered dredged material).

c. Dewatering and Densification.

(1) The removal of excess water from dredged material through active site management may add considerably to containment area storage volume, especially in the case of fine-grained dredged material. The most successful dewatering techniques involve efforts to accelerate natural drying and desiccation of dredged material through increased surface drainage. Dewatering efforts may be implemented in conjunction with other periodic inspection and management activities of the containment.

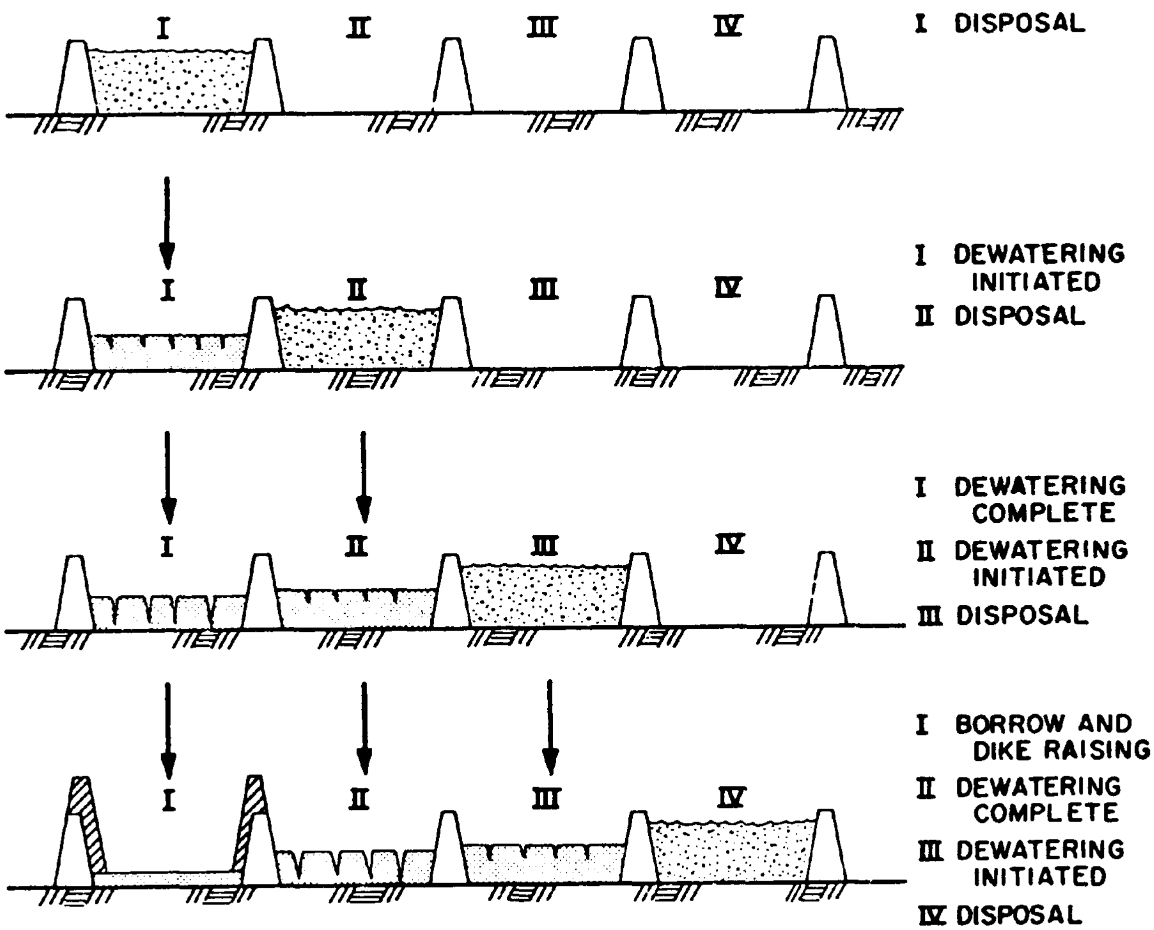


Figure 4-7. Conceptual illustration of sequential dewatering operations possible if disposal site is large enough to contain material from several periodic dredging operations.

(2) Dredged material is usually placed in confined disposal areas in a slurry state. Although a significant amount of water runs off through the overflow weirs of the disposal area, the confined fine-grained dredged material usually sediments/consolidates to only a semifluid consistency that still contains large amounts of water. Not only does the high water content greatly reduce available future disposal volume, but it also makes the dredged material unsuitable or undesirable for any commercial or productive use.

(3) Three major reasons exist for dewatering fine-grained dredged material placed in confined disposal areas:

(a) Promotion of shrinkage and consolidation to increase volume in the existing disposal site for additional dredged material.

(b) Reclamation of the dredged material into more stable soil form for removal and use in dike raising or other engineered construction, or for other productive uses, again increasing volume in the existing disposal site.

(c) Creation of stable, fast land at the disposal site itself, at a known final elevation and with predictable geotechnical properties.

(4) Allowing evaporative forces to dry fine-grained material into a crust while gradually lowering the internal water table is the least expensive and most widely applicable dewatering method. Good surface drainage, rapidly removing precipitation and preventing ponding of surface water, accelerates evaporative drying. Shrinkage forces developed during drying return the material to more stable form; lowering the internal water table results in further consolidation.

(5) Trenching. The most efficient method for promoting good surface drainage is to construct drainage trenches in the disposal area. Because several types of equipment have been found effective for progressive trenching to improve disposal area surface drainage, no unique set of trenching equipment and procedures exists. The proper equipment for any dewatering program will depend upon the following factors: size of the disposal area, whether or not desiccation crust currently exists (and, if so, of what thickness), time available for dewatering operations, type of site access, condition of existing perimeter dikes, time available between disposal cycles, and availability of and rental and operating cost for various types of trenching equipment.

(6) Underdrainage. Underdrainage is another dewatering method which may be used either individually or in conjunction with improved surface drainage. In this procedure, collector pipes are placed in either a naturally occurring or artificially placed pervious layer before dredged material disposal. Upon disposal, free water in the dredged material migrates into the pervious underdrainage layer and is removed via the collector pipe system. Although technically feasible, underdrainage may not be cost-effective in many disposal situations. Detailed discussions of dredged material dewatering are found in WES TR DS-78-11.

d. Disposal Area Reuse. Removal of coarse-grained material and dewatered fine-grained material from containment areas through proper management techniques will further add to capacity and may be implemented in conjunction with dike maintenance or raising. Removal of fine-grained dredged material is a logical followup to successful dewatering management activities and can allow partial or total reuse of the disposal area. A reusable disposal area can be regarded as a dredged material transfer station, where dredged material is collected, processed if necessary, and removed for productive use or inland disposal. The advantages provided by a reusable disposal area (one from which all or a large portion of dredged material is removed) and not by a conventional area are:

(1) Elimination or reduction of land acquisition requirements, except for inland disposal.

(2) Justification for increased costs for high-quality disposal area design and construction.

(3) Long-term availability of disposal areas near dredging sites.

(4) Availability of dredged material for use as landfill or construction material.

Detailed guidance on disposal area reuse is found in WES TR DS-78-12.

4-12. Productive Uses.

a. When planning a reusable disposal area, major consideration should be given as to how the dredged material solids will be used. If off-site productive uses could be found for all the solids being dredged, the site would theoretically have an infinite service life. The fact that dewatered dredged material is a soil, may be analyzed as a soil, and can be used as a soil encourages the productive use of dredged material as a natural resource. The following should be evaluated as potential off-site productive uses for dredged material:

(1) Landfill and construction material.

(2) Surface mine reclamation.

(3) Sanitary landfill cover material.

(4) Agricultural land enhancement.

Compatibility of dredged material with the use in question and feasibility of transport must be considered in evaluating off-site productive use. Detailed guidance is found in WES TR DS-78-21.

b. Containment areas that have been filled also have potential productive use as industrial, recreational, or waterway-related sites. Filled containment areas have been commonly used for commercial/industrial sites, and most ports have such facilities built on former dredged material disposal sites. Recreational use of containment areas is popular because it requires minimum planning and lower cost as compared to industrial/ commercial uses. In addition, the nature of recreation sites with much open space and light construction is especially suited to the weak foundation conditions associated with fine-grained dredged material. Dredged material sites may be used for purposes closely related to the maintenance, preservation, and expanded use of waterways and the surrounding lands, such as shore protection, beach nourishment, breakwaters, river control, etc. Such uses of dredged material sites are influenced by the method and sequence of the dredging operation as well as the layout of the disposal area. Waterway-related use normally involves the creation of landforms and thus permits opportunities for imaginative multiple-use site development. These landforms commonly result in a secondary recreational use.

4-13. Environmental Considerations.

a. Upland disposal of contaminated sediments must be planned to contain potentially toxic materials to control or minimize potential environmental impacts. There are four possible mechanisms for transport of contaminants from upland disposal sites:

(1) Release of contaminants in the effluent during disposal operations.

(2) Leaching into groundwater.

(3) Surface runoff of contaminants in either dissolved or suspended particulate form following disposal.

(4) Plant uptake directly from sediments, followed by indirect animal uptake from feeding on vegetation.

b. The physiochemical conditions of the dredged material at an upland disposal site may be altered substantially by the drainage of excess water. Marked changes in the chemical mobility and biological availability of some contaminants may result. In many cases, contaminant levels exceed applicable surface water quality criteria if mixing and dilution with large volumes of receiving water is limited. Almost all of the contaminants in initial dewatering effluents (with the possible exception of ammonia and manganese) are associated with suspended particulates; increasing suspended solids removal will be effective in reducing these levels.

c. Disposal sites should not be selected where subsurface drainage could result in contaminant levels exceeding applicable criteria for drinking water supplies or adjacent surface waters. Management practices to reduce leaching losses may be beneficial in some cases. Coarse-textured materials will tend to drain freely with little impediment, with time. Some fine-textured dredged material tends to form its own liner as particles settle with percolation drainage water, but it may require considerable time for self-sealing to develop; thus, an artificial liner may be useful for some upland sites. Because of the gradual self-sealing nature of many fine-textured dredged materials, temporary liners subject to gradual deterioration with time may be adequate in many cases.

d. Plant populations may be managed to minimize uptake and environmental cycling of metals from contaminated sediments applied upland. Such a technique may be more effective where plant populations are intensively managed, as in an agricultural operation, since different species and even subspecies differ greatly in their ability to take up and translocate toxic materials. It may be possible to grow crops in which metals tend to accumulate in the plant tissue which is not harvested. Where contaminated dredged material is used to amend agricultural soil or improve other unproductive soils, liming can be an economical and effective method for reducing the bioavailability of many toxic metals.

e. Covering contaminated dredged material with clean soil or clean dredged sediments is a potential management practice that applies to all three of the major disposal alternatives. Where contaminated dredged material is to be used for habitat development, agricultural soils amendment, land reclamation, or as fill for engineering purposes, covering with clean material can be an effective method for isolating contaminants from biological populations growing in or living on the disposal site. The depth of clean material should be sufficient to isolate contaminants from plant roots and burrowing animals. Care should also be exercised to ensure that leaching from contaminated sediments into adjacent groundwater does not take place.

Section V. Habitat Development as a Disposal Alternative

4-14. General Considerations for Habitat Development.

a. Habitat development refers to the establishment of relatively permanent and biologically productive plant and animal habitats. The use of dredged material as a substrate for habitat development offers a disposal technique that is, in many situations, a feasible alternative to more conventional open-water, wetland, or upland disposal options. Refer to Smith (item 8) for more detailed information.

b. Four general habitats are suitable for establishment on dredged material : marsh, upland, island, and aquatic. Within any habitat, several distinct biological communities may occur (fig. 4-8). The determination of the feasibility of habitat development will center on the nature of the surrounding biological communities, the nature of the dredged material, and the site selection, engineering design, cost of alternatives, environmental impacts, and public approval. If habitat development is the selected alternative, a decision regarding the type or types of habitats to be developed must be made. This decision will be largely judgmental, but in general, site peculiarities will not present more than one or two logical options.

c. The selection of habitat development as a disposal alternative will be competitive with other disposal options when the following conditions exist:

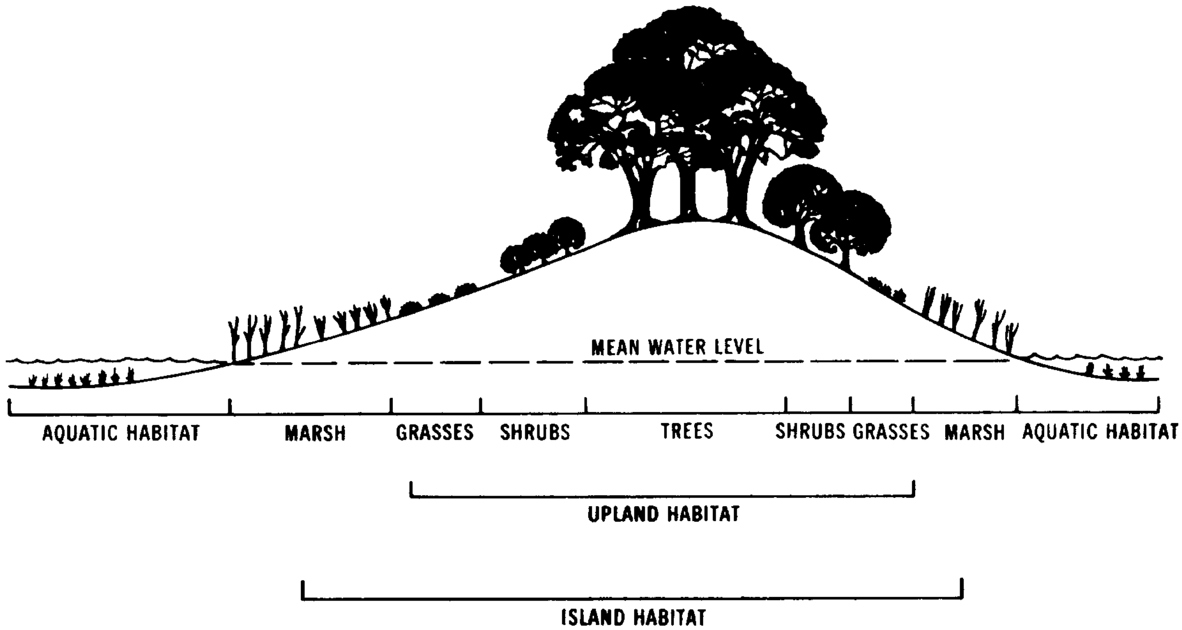


Figure 4-8. Hypothetical site illustrating the diversity of habitat types that may be developed at a disposal site,

(1) Public/agency opinion strongly opposes other alternatives.

(2) Recognized habitat needs exist.

(3) Enhancement measures on existing disposal sites are identified.

(4) Feasibility has been demonstrated locally.

(5) Stability of dredged material deposits is desired.

(6) Habitat development is economically feasible.

d. Disposal alternatives are often severely limited and constrained by public opinion and/or agency regulations. Constraints on open-water disposal and disposal on wetlands, or the unavailability of upland disposal sites, may leave habitat development as the most attractive alternative.

e. Habitat development may have strong public appeal when the need for restoration or mitigation or the need for additional habitat has been demonstrated. This is particularly true in areas where similar habitat of considerable value or public concern has been lost through natural processes or construction activities.

f. Habitat development may be used as an enhancement measure to improve the acceptance of a disposal technique. For example, seagrass may be planted on submerged dredged material, or wildlife food plants established on upland confined disposal sites. This alternative has considerable potential as a low-cost mitigation procedure and may be used to offset environmental impacts incurred in disposal.

g. The concept of habitat development is more apt to be viewed as feasible if it has been successfully demonstrated locally. Even the existence of a pilot-scale project in a given locale will offset the uncertainties often present in the public perception of an experimental or unproven technique.

h. The vegetation cover provided by most habitat alternatives will often stabilize dredged material and prevent its return to the waterway. In many instances this aspect will reduce the amount of future maintenance dredging necessary at a given site and result in a positive environmental and economic impact.

i. The economic feasibility of habitat development should be considered in the context of long-term benefits. Biologically productive habitats have varied but unquestionable value (e.g., sport and commercial fisheries) and are relatively permanent features. Consequently, habitat development may be considered a disposal option with long-term economic benefits that can be applied against any additional costs incurred in its implementation. Most other disposal options lack this benefit.

j. Habitat development may be most economically competitive in situations where it is possible to take advantage of natural conditions or where minor modifications to existing methods would produce desirable biological communities. For example, the existence of a low-energy, shallow-water site adjacent to an area to be dredged may provide an ideal marsh development site and require almost no expenditure beyond that associated with open-water disposal.

4-15. Marsh Habitat Development.

a. Marshes are considered to be any community of grasses and/or herbs which experiences periodic or permanent inundation. Typically, these are intertidal fresh, brackish, or salt marshes or relatively permanently inundated freshwater marshes. Marshes are often recognized as extremely valuable natural systems and are accorded importance in food and detrital production, fish and wildlife cover, nutrient cycling, erosion control, floodwater retention, groundwater recharge, and aesthetic value. Marsh values are highly site specific and must be interpreted in terms of such variables as plant species composition, wildlife use, location, and size, which in turn influence their impact upon a given ecosystem.

b. Marsh creation has been the most studied of the habitat development alternatives, and accurate techniques have been developed to estimate costs and to design, construct, and maintain these systems. Over 100 marshes have been established on dredged material; examples are shown in figures 4-9 and 4-10. Refer to WES TR DS-78-16 for specific information on wetland habitat development. The advantages most frequently identified with marsh development are: considerable public appeal, creation of desirable biological

a. An aerial view of the 420-sq-ft freshwater marsh developed on fine-textured dredged material confined by a sand dike.

b. Within 6 months of dredged material placement, a lush growth of wetland plants had been established by natural colonization.

Figure 4-9. Windmill Point marsh development site, James River, Virginia.

a. A salt marsh was established on poorly consolidated fine-textured dredged material confined behind an earthen dike on this dredged material island.

b. Vigorous growth was obtained from sprigged smooth cordgrass and salt-meadow cordgrass.

Figure 4-10. Apalachicola Bay marsh development site. Apalachicola Bay, Florida .

communities, considerable potential for enhancement or mitigation, and the fact that it is frequently a low-cost option.

c. Marsh development is a disposal alternative that can generate strong public appeal and has the potential for gaining wide acceptance when other techniques cannot. The habitat created has biological values that are readily identified and are accepted by many in the academic, governmental, and private sectors. However, application requires an understanding of local needs and perceptions and of the effective limits of the value of these ecosystems.

d. The potential of this alternative to replace or improve marsh habitats lost through dredged material disposal or other activities is frequently overlooked. Techniques are sufficiently advanced to design and construct productive systems with a high degree of confidence. Additionally, these habitats can often be developed with very little increase in cost above normal project operation, a fact attested to by hundreds of marshes that have been inadvertently established on dredged material.

e. The following problems are most likely to be encountered in the implementation of this alternative: unavailability of appropriate sites, loss of other habitats, release of contaminants, and loss of the site for subsequent disposal.

f. The most difficult aspect of marsh development is the location of suitable sites. Low-energy, shallow-water sites are most attractive; however, cost factors will become significant if long transport distances are necessary to reach those sites. Protective structures may be required if low-energy sites cannot be located, which can add considerably to project cost.

g. Marsh development frequently means the replacement of one desirable habitat with another, and this will likely be the source of most opposition to this alternative. There are few reliable methods of comparing the various losses and gains associated with this habitat conversion; consequently, relative impact may best be determined on the basis of the professional opinion of local authorities.

h. The potential for plants to take up contaminants and then release them into the ecosystem through consumption by animals or decomposition of plant material should be recognized when contaminated sediments are used for habitat development. Although this process has not been shown to occur often, techniques are available to determine the probability of uptake.

i. Development of a marsh at a given site can prevent the subsequent use of that area as a disposal site. In many instances, any further development on that site would be prevented by State and Federal regulations. Exceptions may occur in areas of severe erosion or where the initial disposal created a low marsh and subsequent disposal would create a higher marsh.

j. There are types of wetland habitat development other than marshes, such as bottomland hardwoods in freshwater areas. These are addressed in WES TR DS-78-16.

4-16. Upland Habitat Development.

a. Upland habitats encompass a variety of terrestrial communities ranging from bare soil to dense forest. In its broadest interpretation, habitat occurs on all but the most disturbed upland disposal sites. For example, a gravelly and bare freshwater disposal area may provide nest sites for killdeer; weedy growth may provide cover for raccoons or a food source for seed-eating birds; and water collection in desiccation cracks may provide breeding habitat for mosquitoes. Man-made habitats will develop regardless of their management; however, the application of sound management techniques will greatly improve the quality of those habitats and the speed with which they are populated.

b. Upland habitat development has potential at hundreds of disposal sites throughout the United States. Its implementation is largely a matter of the application of well-established agricultural and wildlife management techniques. Examples of successful sites are shown in figures 4-11 and 4-12. Refer to WES TR DS-78-17 for more detailed information on upland habitat development. Upland habitat development as a disposal option has several distinct advantages, including: adaptability, improved public acceptance, creation of biologically desirable habitats, elimination of problem areas, low-cost enhancement or mitigation, and compatibility with subsequent disposal.

c. Upland habitat development may be used as an enhancement or mitigation measure at new or existing disposal sites. Regardless of the condition or location of a disposal area, considerable potential exists to convert it into a more productive habitat. For example, small sites in densely populated areas may be keyed to small animals adapted to urban life, such as seed-eating birds and squirrels. Large tracts may be managed for a variety of wildlife, including waterfowl, game mammals, and rare or endangered species.

d. The knowledge that a site will ultimately be developed into a useful area, be it a residential area, park, or wildlife habitat, improves public acceptance. Many idle and undeveloped disposal areas that are now sources of local irritation or neglect would directly benefit from upland habitat development, and such development may well result in more ready acceptance of future disposal projects.

e. In general, upland habitat development will add little to the cost of disposal operations. Standard procedures may involve liming, fertilizing, seeding, and mowing. A typical level of effort is similar to that applied for erosion control at most construction sites and considerably less than that required for levee maintenance.

f. Unless the target habitat is a long-term goal such as a forest, upland habitat development will generally be compatible with subsequent disposal operations. In most situations, a desirable vegetative cover can

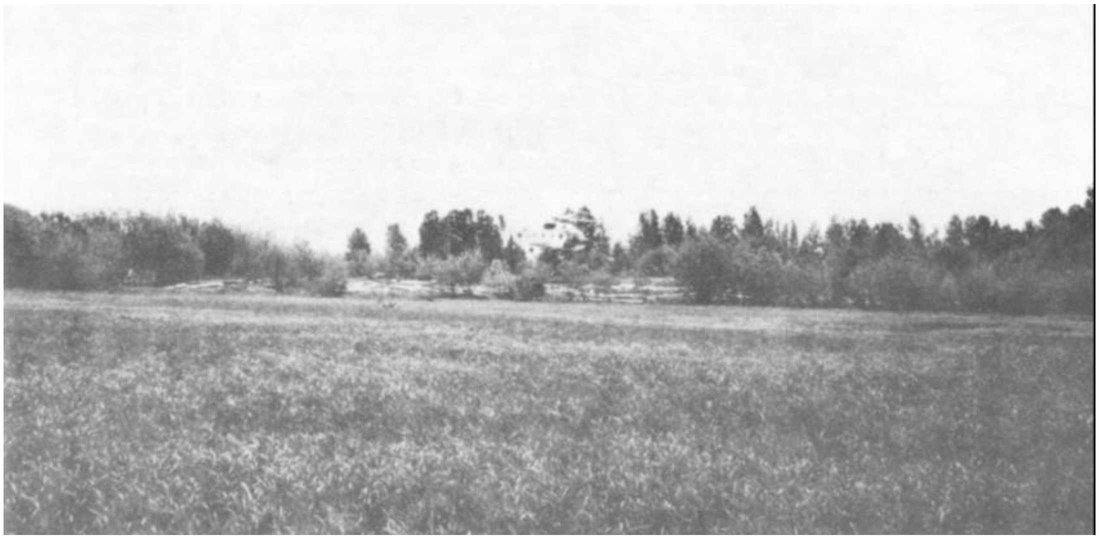


Figure 4-11. Barley was planted on this sandy dredged material island in the Columbia River, Oregon, greatly improving its value to wildlife,

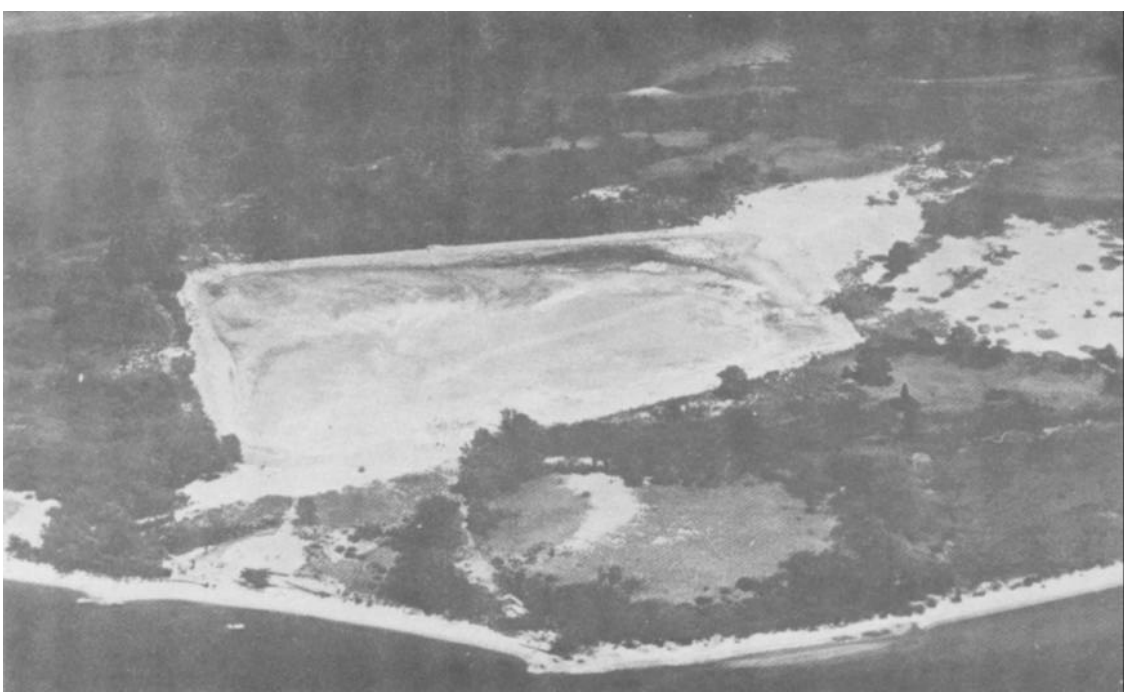


Figure 4-12. Sandy and silty dredged material were combined at Nott Island, Connecticut, to produce a pasture for wild geese.

be produced in one growing season. Subsequent disposal would simply require recovery of the lost habitat. Indeed, the maintenance of a particular vegetation stage may require periodic disposal to retard or set back plant succession.

g. The primary disadvantage of this alternative is related to public acceptance. The development of a biologically productive area at a given site may discourage subsequent disposal or modification of land use at that site. This problem can be avoided by the clear identification or establishment of future plans before habitat development, or by the establishment and maintenance of biological communities recognized as being most productive in the earlier stages of succession. In the latter case, subsequent disposal may be a necessary management tool.

h. Some habitat types will require management. For example, if high-productivity annual plants are selected for establishment (i.e., corn or barley as prime wildlife foods), then yearly planting will be necessary. If the intent is to maintain a grassland or open-field habitat, planting may be required only initially, but it may be necessary to mow the area every 1 to 5 years to retard colonizing woody vegetation. In most cases, it will be possible to establish very low-maintenance habitats, but if the intent is to establish and perpetuate a given habitat type, long-term management may be essential and expensive.

4-17. Island Habitat Development.

a. Dredged material islands range in size from an acre to several hundred acres. Island habitats are terrestrial communities completely surrounded by water or wetlands and are distinguished by their isolation and their limited food and cover. Because they are isolated and relatively predator-free they have particular value as nesting and roosting sites for numerous species of sea and wading birds; e.g., gulls, terns, egrets, herons, and pelicans. The importance of dredged material islands to nesting species tends to decrease as the size increases because larger islands are more likely to support resident predators. However, isolation is more important than size; and thus large isolated islands may be very attractive to nesting birds. Dredged material island habitats are pictured in figures 4-13 and 4-14. Refer to WES TR DS-78-18 for specific information regarding island habitat development.

b. Dredged material islands are found in low- to medium-energy sites throughout the United States. Typically, these are sandy islands located next to navigation channels and are characteristic of the Intracoastal Waterway. In recent years, many active dredged material islands have been diked to improve the containment characteristics of the sites.

c. The importance of dredged material islands as nesting habitats for sea and wading birds cannot be overemphasized. In some states (e.g. North Carolina and Texas) most nesting of these colonial species occurs on man-made islands.

d. Island habitat development has the following advantages: it

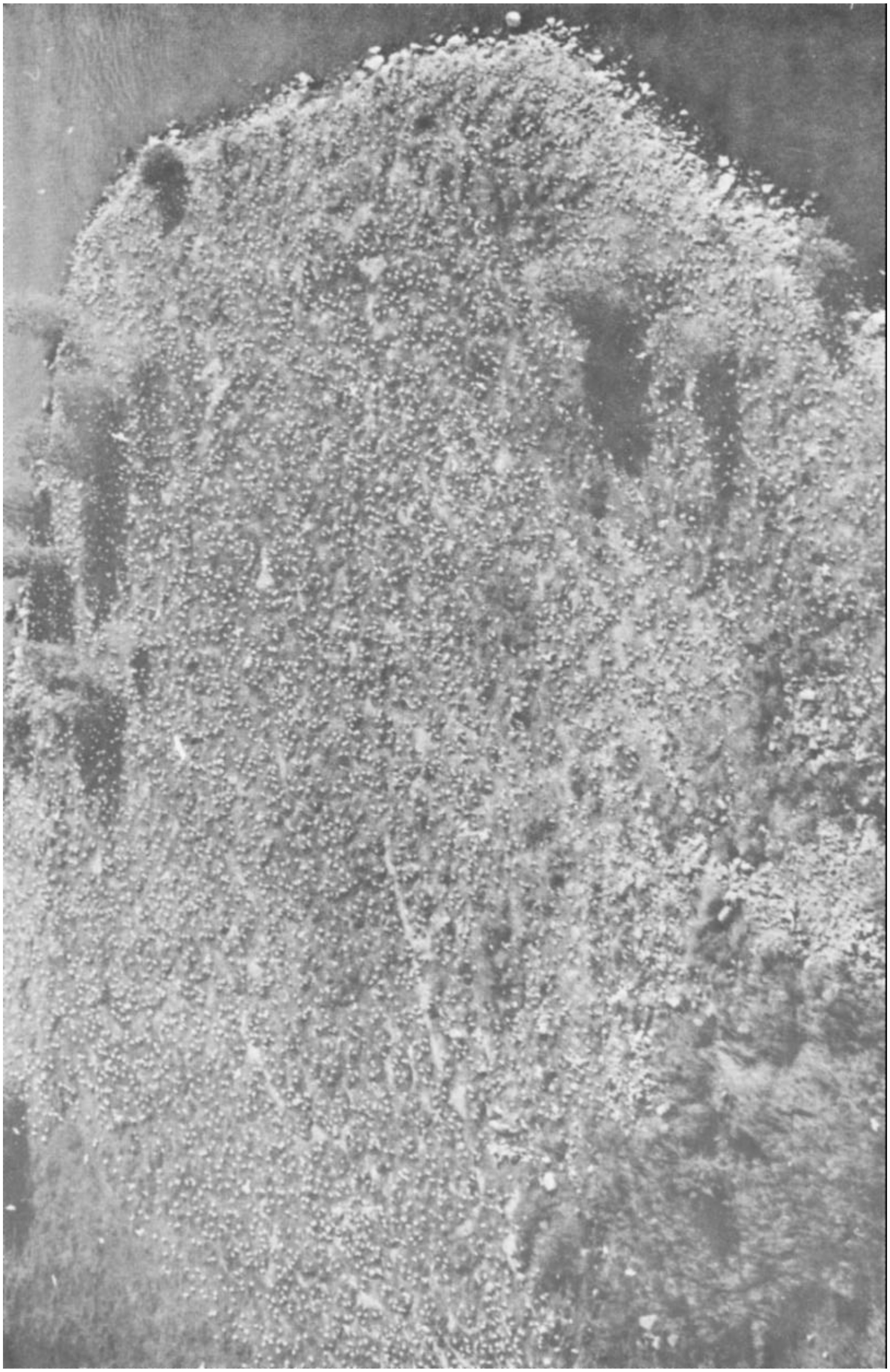


Figure 4-13. Ring-billed gull colony located on a dredged material island in the Detroit River, Michigan. The site supported 5040 nests in 1976 and 5290 nests in 1977.

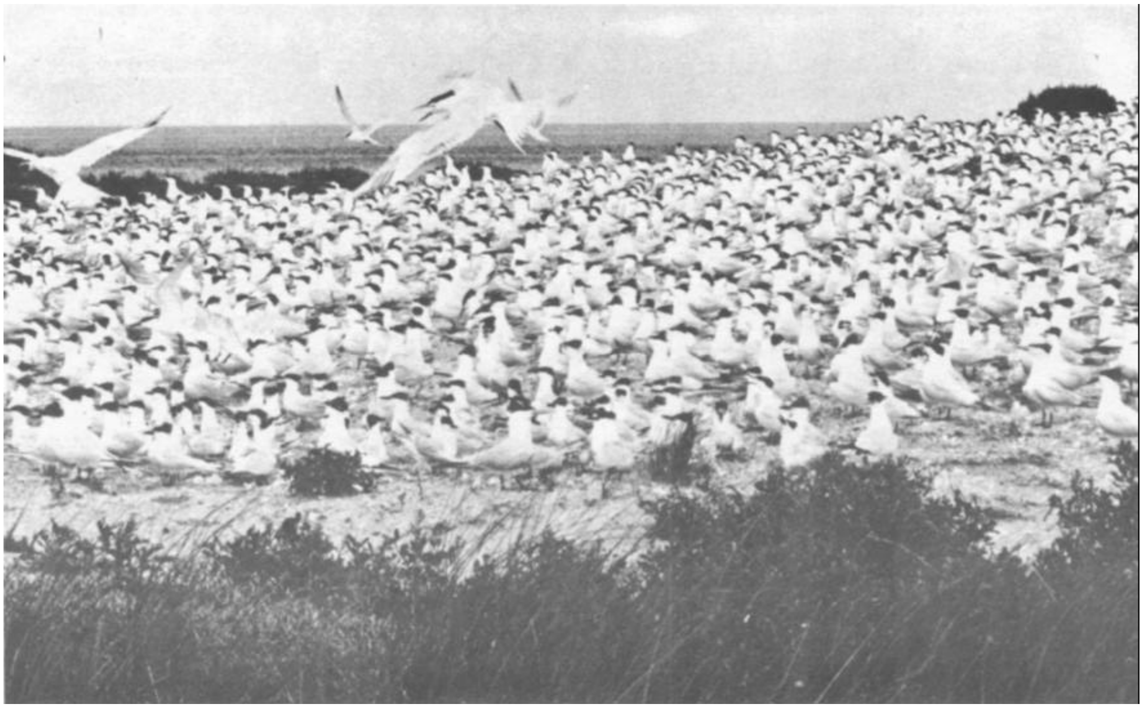


Figure 4-14. Mixed-species colony of royal and Sandwich terns located on a dredged material island in Pamlico Sound, North Carolina. The colony comprised 2988 royal tern nests and 897 Sandwich tern nests,

employs traditional disposal techniques, it permits reuse of existing disposal areas, it provides critical nesting habitats, and its management is conducive to subsequent disposal.

e. Island habitat development utilizes a traditional disposal technique: the confined or unconfined disposal of dredged material in marsh or shallow water or on existing islands. Consequently, unconventional operational problems seldom occur in its implementation.

f. In many coastal areas, the careful selection of island locales and placement will encourage use by colonial nesting birds. Properly applied, island habitat development is an important wildlife management tool: it can replace habitats lost to other resource priorities, provide new habitats where nesting and roosting sites are limiting factors, or rejuvenate existing disposal islands.

g. Planned disposal on existing dredged material islands is often conducive to their management for wildlife. Nesting is almost always keyed to a specific vegetation successional stage, and periodic disposal may be used to retard succession or set it back to a more desirable state. As a practical matter, disposal on existing islands has largely replaced new island development because of opposition to the loss of open-water and bottom habitats. Consequently, habitat development on dredged material islands will frequently be keyed to the disposal on and management of existing islands.

h. Island habitat development has the following disadvantages: it may interrupt hydrologic processes, it may destroy open-water or marsh habitats, and it requires careful placement of material and selection of the disposal season to prevent disruption of active nesting.

i. Alteration of the water-energy regime by the placement of barriers such as islands deserves particular attention because it can change the temperature, salinity, circulation patterns, and sedimentation dynamics of the affected body of water. Large-scale projects or projects in particularly sensitive areas may warrant the development of physical, chemical, and biological models of the aquatic system before project implementation.

j. Dredged material islands, by the nature of their location, may reduce the presence of wetlands and/or open-water and their associated benthic habitats. This impact will be minimized by careful site selection or disposal on existing sites. Containment behind dikes will lessen the lateral spread of material but will probably adversely affect the value of the island to birds.

k. Disposal on any dredged material island should be immediately preceeded by a visit to determine if the site is an active nesting colony. The use of dredged material islands by birds will occur with or without management. When colonies are present, scheduling of subsequent disposal operations and placement of material should be planned to minimize disruption of the disposal operations as well as of the nesting colonies involved. Destruction of the nests of all colonial waterbirds is a criminal offense punishable by fine and/or imprisonment.

4-18. Aquatic Habitat Development.

a. Aquatic habitat development refers to the establishment of biological communities on dredged material at or below mean tide. Potential developments include such communities as tidal flats, seagrass meadows, oyster beds, and clam flats. The bottoms of many water bodies could be altered using dredged material; in many cases this would simultaneously improve the characteristics of the site for selected species and permit the disposal of significant quantities of material. Planned aquatic habitat development is a relatively new and rapidly moving field; however, with the exception of many unintentional occurrences and several small-scale demonstration projects, this alternative is largely untested. There are no general texts or manuals currently available; however, potential users may obtain updated information by contacting the Environmental Laboratory at the U. S. Army Engineer Waterways Experiment Station.

b. The major advantages of aquatic development are that it produces habitats that have high biological production and potential for wide application and can effectively complement other habitats.

c. Aquatic habitats may be highly productive biological units. Seagrass beds are recognized as exceptionally valuable habitat features, providing both food and cover for many fish and shellfish. Oyster beds and clam flats have high recreational and commercial importance. Dredged material disposal projects affecting aquatic communities often incur strong criticism, and in these instances reestablishment of similar communities may be feasible as a mitigation or enhancement technique. In many instances it will be possible to establish aquatic habitats as part of marsh habitat development.